King County 2023 Consumption-Based Emissions Inventory Report

November 2025

Prepared by EcoDataLab for King County Executive Climate Office

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Glossary

Business investment emissions	Business investment emissions refer to emissions associated with businesses' investments, including structures (like office buildings and manufacturing plants), equipment (like machinery and trucks) and intellectual property (designs, formulas, etc.), as well as changes in the inventory of goods that businesses hold in stock. Emissions associated with production inputs or processes are not included with business investment emissions, as they are instead allocated to households and governments.
Capital asset	Capital assets are tangible and intangible assets which include structures, equipment, intellectual property, and business inventory.
Carbon dioxide equivalent (CO_2e)	A unit that allows emissions of various greenhouse gases (such as carbon dioxide [CO_2], methane [CH_4], and nitrous oxide [N_2O]) to be expressed as a single unit of measurement.
Consumption-based emissions inventory (CBEI)	A consumption-based emissions inventory (CBEI) is a calculation of all greenhouse gases (GHGs) associated with producing, transporting, and using products and services consumed by a particular community or entity in a given time (typically one year).
Consumption category	In the communitywide CBEI, emissions are categorized into five consumption categories: transportation, housing, food, goods, and services.
Direct emissions	Direct emissions, in the context of the CBEI, refer to emissions that are emitted within a jurisdiction's boundaries, typically as a result of production of goods or services, or from energy use such as gasoline or natural gas.
Emissions	Refers to greenhouse gas emissions (see *GHG*).
Emission factor	An emission factor is a measure of the mass of GHG emissions (typically in CO_2e) relative to a unit of activity.
Equipment	All equipment purchased by a business or government for its own use. Equipment includes machinery for manufacturing, vehicles, furniture, computers, appliances, and other durable items.

Final consumers	Final consumers refer to the end users of a product or service. Final consumers include households, governments, and businesses (see final demand)
Final demand	Final demand includes demand (consumption) by all households and government, as well as governments and businesses' multi-year investments in capital assets (such as buildings, equipment and vehicles, intellectual property, and inventory).
Global Warming Potential (GWP)	A measurement of how much a particular GHG contributes to global warming relative to carbon dioxide (CO_2). It is used to convert a given mass of a GHG to the equivalent metric tons of carbon dioxide equivalent (CO_2e) to express total emissions using a common unit.
Goods and services	The phrase "goods and services" refers to everything exchanged in the economy. This is distinct from either the "goods" or "services" categories of consumption, which refer specifically to a limited set of goods or services, respectively, which are not included in the other categories of transportation, housing, or food.
Greenhouse Gases (GHGs)	Compound gases that trap heat and emit longwave radiation in the atmosphere causing the greenhouse effect.
Indirect emissions	Indirect emissions refer to emissions which occur outside of a jurisdiction, such as associated with the production of goods and services, or travel, outside the jurisdiction.
Intellectual property (IP)	IP refers to intangible assets that are the result of creativity such as research and development, software, patents, copyright, designs, trademarks, or brands. IP emissions are the emissions associated with producing these assets, including from building energy use and other goods and services consumed by the business in generating the IP.
Metric ton (MT)	1,000 kilograms
Million metric ton (MMT)	1,000,000,000 kilograms
North American Industry Classification System (NAICS)	NAICS is a system for classifying businesses into industry groupings, based on primary business activity, used across the US, Canada, and Mexico. NAICS uses a hierarchical numbering system of up to six digits, where the first 2 digits

	indicate the sector, the 3rd digit indicates sub-sector, 4th digit industry group, 5th digit industry, and 6th digit detailed industry.
Subcategory	Each CBEI emissions category consists of multiple sub-categories.
Ton (t)	One metric ton (1,000 kilograms).
Vehicle fuel economy	Distance traveled (in miles) per gallon of fuel.
VMT	Vehicle miles traveled.

Executive Summary

A communitywide consumption-based emissions inventory (CBEI) estimates the greenhouse gas (GHG) emissions associated with the total final demand (consumption) of goods and services within a community, including consumption by households, governments, and businesses' investments in capital goods (such as buildings or inventory). King County's CBEI evaluates these emissions for all households in the county.

Total consumption-based emissions across King County were roughly 47.3 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) in 2023, including 33.4 $MMTCO_2e$ from households, 6.1 $MMTCO_2e$ from government, and 7.9 $MMTCO_2e$ from businesses (components may not sum due to rounding). This is nearly double the communitywide geographic emissions inventory of 25.5 $MMTCO_2e$, which only considers emissions occurring within King County's geographic boundaries[1].

The average household in King County was responsible for roughly 35.1 metric tons of carbon dioxide equivalent ($MTCO_2e$) annually, or about 14.9 $MTCO_2e$ per person[2]. Two-thirds of government emissions came from state and local governments' consumption of goods, services, and energy, while business investment emissions were nearly equal across structures, equipment (including vehicles), and intellectual property.

Some of the largest sources of emissions in the King County CBEI included gasoline for transportation, building energy use (electricity and natural gas, including both in homes and in government and other businesses), building construction (across both business and government), government goods and services, meat and dairy products, air travel, and furnishings and appliances and other equipment.

Emissions per household declined from 41.6 $MTCO_2e$ in 2007 to 35.1 $MTCO_2e$ in 2023, a 16% decline. The primary drivers for the decline are improving vehicle fuel economy, reductions in electricity emissions intensity, and economy-wide reductions in the emissions associated with purchased goods and services. King County's total number of households grew by 24% in this same time period, or roughly 182,000 households. As a result, King County's communitywide emissions have grown from about 31.9 million $MTCO_2e$ ($MMTCO_2e$) in 2007 to about 33.3 $MMTCO_2e$ in 2023.

However, King County's per household emissions (35.1 $MTCO_2e$) are lower than Washington's statewide average (36.5 $MTCO_2e$). This is largely due to fewer emissions from gasoline and electricity usage in King County (a result of both lower vehicle miles traveled and higher vehicle fuel economy, as well as less electricity usage and fewer

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[1] King County, *King County 2025 Strategic Climate Action Plan*. https://cdn.kingcounty.gov/-/media/king-county/depts/executive/climate-office/documents/2025scap/kc_exec_proposed_scap_planonly_compressed.pdf

[2] The King County 2025 Strategic Climate Action Plan (SCAP) estimates that the average resident contributes 10.8 $MTCO_2e$. This SCAP estimate only considers emissions that occur geographically within King County. The CBEI considers emissions that may occur anywhere in the world as a result of household consumption.

emissions from electricity). While King County's growth led to more communitywide consumption-based emissions overall, if those households had located elsewhere in Washington, there would have been even greater emissions - over 2 million $MTCO_2e$ since 2007, or about 255,000 $MTCO_2e$ per year by 2023.

Emissions from government have increased by about 1 $MMTCO_2e$ since 2007 (from 5.1 to 6.1 $MMTCO_2e$), while emissions from business investments have decreased by about 0.3 $MMTCO_2e$ (from 8.2 to 7.9 $MMTCO_2e$). Overall, communitywide emissions in King County have increased by about 2.1 $MMTCO_2e$ since 2007 (from 45.2 to 47.3 $MMTCO_2e$).

This CBEI supports the 2025 King County Strategic Climate Action Plan (SCAP), including outcomes envisioned in the *Design Out Waste* flagship and actions in the *Circular Economy* focus area. King County's goal for a circular economy is to achieve zero waste of resources by reducing consumption and waste generated, and increasing reuse, recycling, and composting. The County is committed to achieving a circular economy where waste is minimized, and materials remain in use longer. By highlighting the embodied emissions in the goods and services consumed in the county, this CBEI report shows the magnitude of emission reduction opportunities available from reducing or avoiding waste and increasing reuse.

Introduction

The King County communitywide consumption-based emissions inventory (CBEI) is an estimate of the greenhouse gas (GHG) emissions associated with the consumption (final demand) of goods and services within the county.

Both CBEIs and more traditional geographic GHG inventories attribute some portion of global emissions to a given community. King County's traditional geographic-based inventory looks primarily at emissions that physically occur within the county. It considers all emissions generated directly by activity in the county: from local driving and transportation, building energy use, waste generation, and more.

In contrast, the CBEI looks at all emissions that occur in the lifecycle of any goods and services consumed by county residents or governments. The CBEI also incorporates lifecycle emissions from business and government investments in things like buildings and equipment (fixed capital). While these emissions are attributed to consumers located within the county (households, governments, and businesses), the emissions themselves may occur anywhere in the world. Figure 1 shows the differences and overlap between these two inventory types.

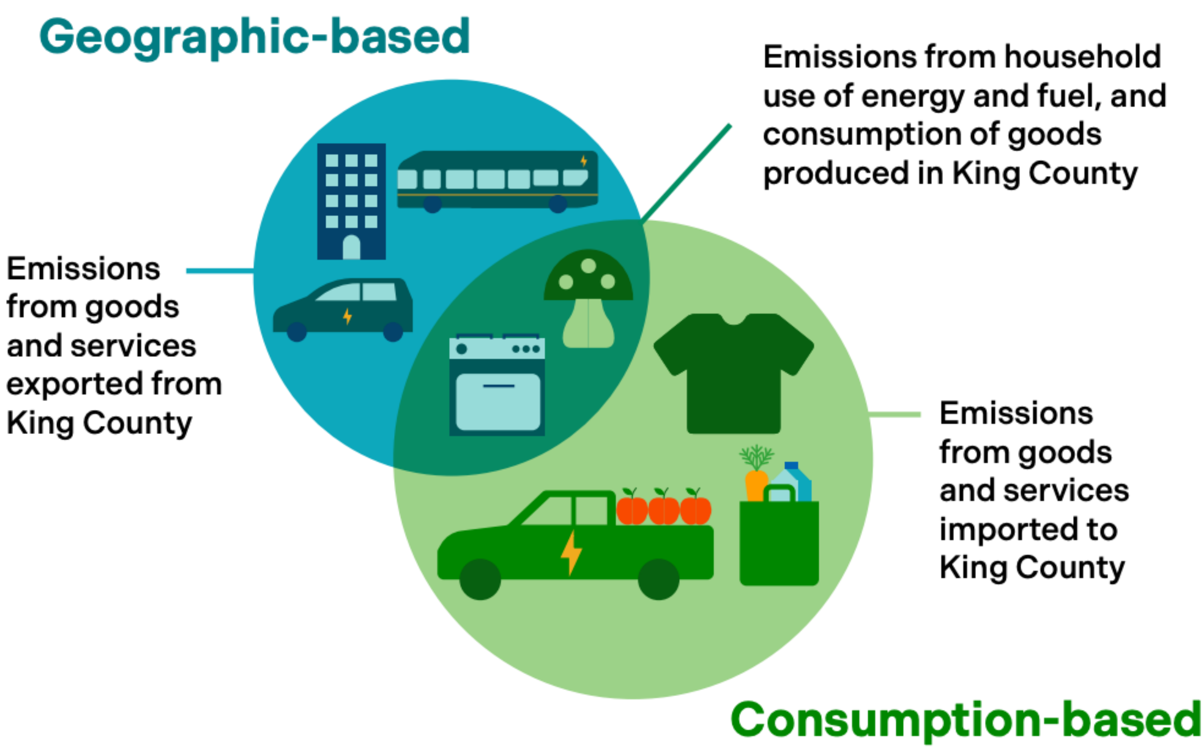


Figure 1. Geographic- and Consumption-based Inventory Comparison

The geographic and consumption-based emissions inventories are complementary and partially overlapping. Both consider emissions from household use of energy and fuels (like gasoline, electricity, and natural gas), as well as the emissions associated with goods and services produced within the county and consumed by residents. The geographic inventory also considers emissions generated locally by visitors, or in the production of goods and services that are sold to consumers outside of the county. Meanwhile, the CBEI will also consider emissions from goods and services imported into the county.

The CBEI breaks out household emissions into five categories of transportation, housing, food, goods, and services, with 29 sub-categories across these five major categories. Fixed capital investments (by governments and businesses) and government purchases cannot be attributed directly to specific households, so those consumers are separately evaluated. Government emissions in the CBEI include government consumption of goods, services, and energy, as well as investments in capital (structures, equipment, and intellectual property). Business emissions in the CBEI include investments in structures, equipment, and intellectual property, as well as changes in inventory (unsold products). Emissions associated with the various inputs directly used by businesses in producing their goods and services (such as raw materials, electricity, etc.) are allocated to the final consumer of the ultimate good or service, not to the business as an intermediate consumer.

Government emissions are organized across federal defense, federal non-defense, and state and local government sectors, while business investment emissions are organized by North American Industry Classification System (NAICS) 2-digit sector-level codes.

This CBEI evaluates these emissions across King County as a whole. The household component of the CBEI is further analyzed for each census tract.

King County's CBEI helps provide a more comprehensive picture of the GHG emissions that the County can influence. The CBEI serves as a reference point to understand the relative sizes of different sources of emissions, both within the CBEI and in the geographic GHG inventory. This helps to highlight key areas for local action to reduce emissions. The CBEI reflects communitywide averages, based on modeled estimates using a combination of local and national data, and is not reflective of any particular household's individual choices. In addition, because the CBEI relies on a combination of local, state, and national data, it may not capture all distinct local characteristics that could influence consumption patterns or emissions. The CBEI also has limited ability to directly track the effects of local policies, and should be combined with more granular data collection and analysis for specific policy implementation.

2023 Community-wide CBEI Results

In 2023, King County was responsible for about 47.3 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) of consumption-based emissions. Households are responsible for 71%, or 33.4 $MMTCO_2e$, of consumption-based emissions. Governments and business investments contribute 13% (6.1 $MMTCO_2e$) and 17% (7.9 $MMTCO_2e$), respectively. The average King County household had about 35.1 $MTCO_2e$ attributable to household consumption annually, or about 14.9 $MTCO_2e$ per person.

Table 1. King County Community-Wide Totals (2023)

Final Consumer	Total Emissions ($MMTCO_2e$)	Share of Category	Share of Total
Households	**33.4**	**-**	**71%**
Transportation	11.6	35%	24%
Services	6.8	20%	14%
Housing	5.5	16%	12%
Food	5.5	16%	12%
Goods	4.1	12%	9%
Governments	**6.1**	**-**	**13%**
Goods & Services	4.7	77%	10%
Buildings	1	17%	2%
Equipment	0.2	3%	0%
Intellectual Property	0.2	2%	0%
Businesses	**7.9**	**-**	**17%**
Buildings	2.7	35%	6%
Equipment	2.7	34%	6%
Intellectual Property	2.5	32%	5%
Inventory[3]	-0.1	-1%	0%
Total	**47.3**	**-**	**100%**

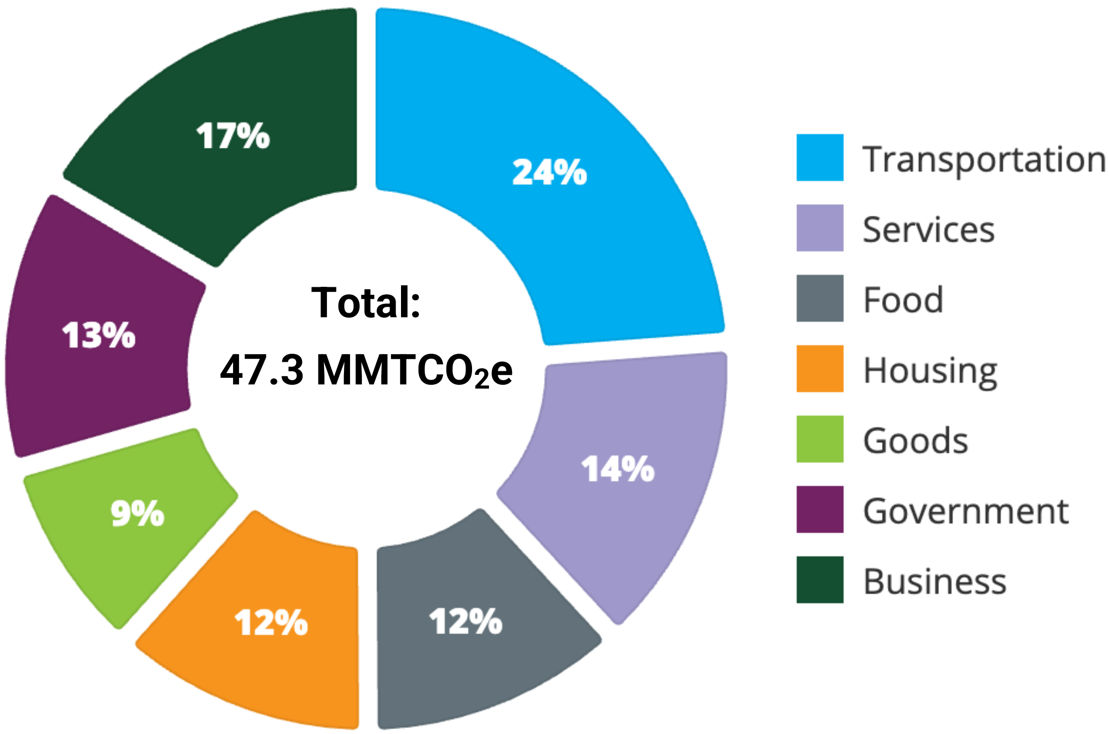
Every household in King County is likely to have slightly different emissions, and some households likely vary significantly from this average. The average household in King County in 2023 had a household income of $149,408, with 2.4 people and 1.6 vehicles, living in a 5.7-room home[4]. Differences in household size, spending, housing, travel, and other factors will affect any individual household's emissions. However, as an overall average estimate, this provides a perspective into the relative magnitude of consumption-based emissions in the county. This inventory further breaks down these emissions into categories and sub-categories, identifies the lifecycle stages where emissions occur, the geographic location of emissions, and the census tracts (neighborhoods) with highest and lowest per-household emissions, all of which can

[3] Negative inventory emissions indicates a drawdown of existing inventory stockpiles in 2023.
[4] EcoDataLab estimates based on American Community Survey 1-year county-level estimates, provided by U.S. Census.

provide additional insight into the key sources of emissions and opportunities for taking action.

Figure 2 provides an overview of the 2023 average household emissions in King County across the five major household consumption categories, plus government and businesses.

Figure 2. King County Communitywide Consumption-Based Emissions (2023)



Methodology Summary

The communitywide CBEI incorporates emissions from households, businesses, and governments. Each of these final consumers is modeled separately and estimated based on a combination of local, state, and national data.

Household consumption-based emissions are calculated based upon estimates of either household spending or household activity (such as driving or energy usage) by subcategory. No personal or individual data is used. Instead, the household CBEI relies on a predictive computer model to estimate household spending or activity by subcategory, based on a variety of household characteristics. The household spending model is based upon data from the U.S. Consumer Expenditures Survey (CEX), using local household characteristics for King County to estimate household spending. These spending estimates are combined with emissions intensity data by subcategory, derived from the national U.S. Environmentally-Extended Input-Output Model (USEEIO) data, to estimate the greenhouse gas impacts associated with household consumption.

This household spending-based emissions data is then combined with modeled estimates of household automobile usage (from the National Household Transportation

Survey [NHTS]), along with Washington-specific local vehicle fuel economy data (aggregated from the ZIP code). The King County CBEI also uses countywide average household electricity and natural gas usage and emissions data from local utility providers, and county-level household water data from the U.S. Geological Service. Energy use is scaled to census tracts using a model based on the Residential Energy Consumption Survey (RECS). Due to modeling limitations, all census tracts are assumed to have the same (countywide average) water and waste generation.

The household characteristics used to estimate household consumption include household income, household size, home size (number of rooms), home ownership, vehicle ownership, and college education. Higher incomes are an important factor that drive higher consumption-based emissions, as higher income households have more money available to spend, resulting in greater consumption and emissions. However, different types of purchases produce different amounts of emissions for each dollar spent – for example, one dollar of gasoline, when burned for transportation, generates far more emissions than one dollar of fruits and vegetables. The other household characteristics help predict different patterns of spending which, when combined with different emission factors for different types of purchases, lead to differences in household emissions beyond simply differences in income. For example, households with larger homes (more rooms) tend to buy more furniture, while households with higher levels of education (college attainment) tend to spend more on education. Typically, households spend most of their income, and so it can be challenging to reduce consumption overall. However, policy and cultural factors can help encourage individuals to make consumption choices that are less emissions-intensive – for example, buying an electric car instead of a gas car, choosing local entertainment like concerts and eating out over air travel, or eating plant-based foods instead of meat and dairy products. Some of the lowest emission expenditure categories (on a per dollar basis) include housing costs, clothing, insurance, and education, while some of the highest include air travel, gasoline, meat and dairy products, and alcoholic beverages.

Business investment emissions are calculated from the USEEIO State Model data on non-residential fixed investment and emissions per dollar by industry for the state of Washington. These statewide emissions are then scaled to each county based on a combination of national data on capital investments (from the Annual Capital Expenditures Survey [ACES] dataset), and local data on employment by industry (from the Bureau of Labor Statistics [BLS] Quarterly Census of Employment and Wages [QCEW]). The ACES dataset is used to allocate emissions from capital investments to industries, while the QCEW data is used to allocate those investments by industry to counties[5].

[5] For example, if 50% of national capital investments in structures are in service industries, Washington State is assumed to have 50% of its capital investments in structures coming from service industries. If King County has 20% of the service industry employees in Washington state, King County is assumed to have 20% of Washington's investments in structures from services industries.

Government emissions are similarly calculated at the state level using USEEIO State Model data and subsequently weighted to King County based upon employment data. The USEEIO State Model data provides aggregated estimates of total consumption among all state and local governments across the state, as well as statewide federal defense and non-defense consumption, and King County receives an employment-weighted share of those emissions (for example, if King County has 25% of all state and local government employees in Washington, it is allocated 25% of Washington's state and local government emissions). The government employment data used to scale the statewide USEEIO State Model government emissions data is a combination of QCEW data (for state and local and federal non-defense employment) and Department of Defense data from the Office of Local Defense Community Cooperation and Defense Manpower Data Center (for defense employment).

This CBEI approach has some important limitations. Firstly, while the CBEI model allows for tracking some policy effects, it does not capture all changes in policy, behavior, infrastructure, or technology that may affect consumption or associated emissions. Secondly, due to data limitations, the current approach does not include an estimate of total error, which ranges from household survey and census errors to modeling, categorization, or other economic or environmental data errors. U.S. EPA does not publish margins of error for its emission factor estimates. Lastly, the CBEI model relies on significant assumptions to scale statewide government and business emissions data to the county level, which may not reflect actual local activities.

As a result, the CBEI is primarily helpful in identifying the *relative* sizes of different sources of emissions. Because it is a modeled estimate with uncertain margins of error, values that are very close together (e.g. 1.4 versus 1.5) should not be assumed to be meaningfully different. Instead, the CBEI should primarily be used to determine which sources of emissions are *significantly* larger or smaller (e.g. 9.2 vs 3 vs 1.4). Understanding the major sources of emissions helps policymakers and program managers to identify the most effective strategies to achieve emission reductions, with limited financial and staff resources. When adopting or implementing policies, additional data collection mechanisms should be considered to ensure the effects can be tracked separately from the CBEI itself, which may not capture the effects of behavior-based policy changes (such as signage, education, or other efforts to persuade people to change consumption patterns independent of demographics and household characteristics).

For additional information on the methodology, see Appendix A – Community-wide Consumption-based Emissions Inventory Methodology. The detailed calculations are not presented in the body of this report.

Household Emissions

Figure 3 provides an overview of the 2023 emissions in King County across the five household consumption categories. For a typical household, transportation accounts for about 12.2 $MTCO_2e$, or 35% of total household emissions. Services accounted for about 7.1 $MTCO_2e$, or 20%; food accounted for about 5.8 $MTCO_2e$, or 17%; housing for about 5.7 $MTCO_2e$, or 16%; and goods for about 4.3 $MTCO_2e$, or 12%. Within these categories, gasoline (transportation), healthcare (services), and electricity (housing) were the largest sources of emissions, with 9.2, 3.9, and 2.4 $MTCO_2e$, respectively. Within the food category, meat and dairy together accounted for 1.9 $MTCO_2e$, while the largest subcategory of goods was furnishings and appliances at 1.7 $MTCO_2e$.

Figure 3. King County Average Per Household Category Breakdown ($MTCO_2e$ per household, 2023)

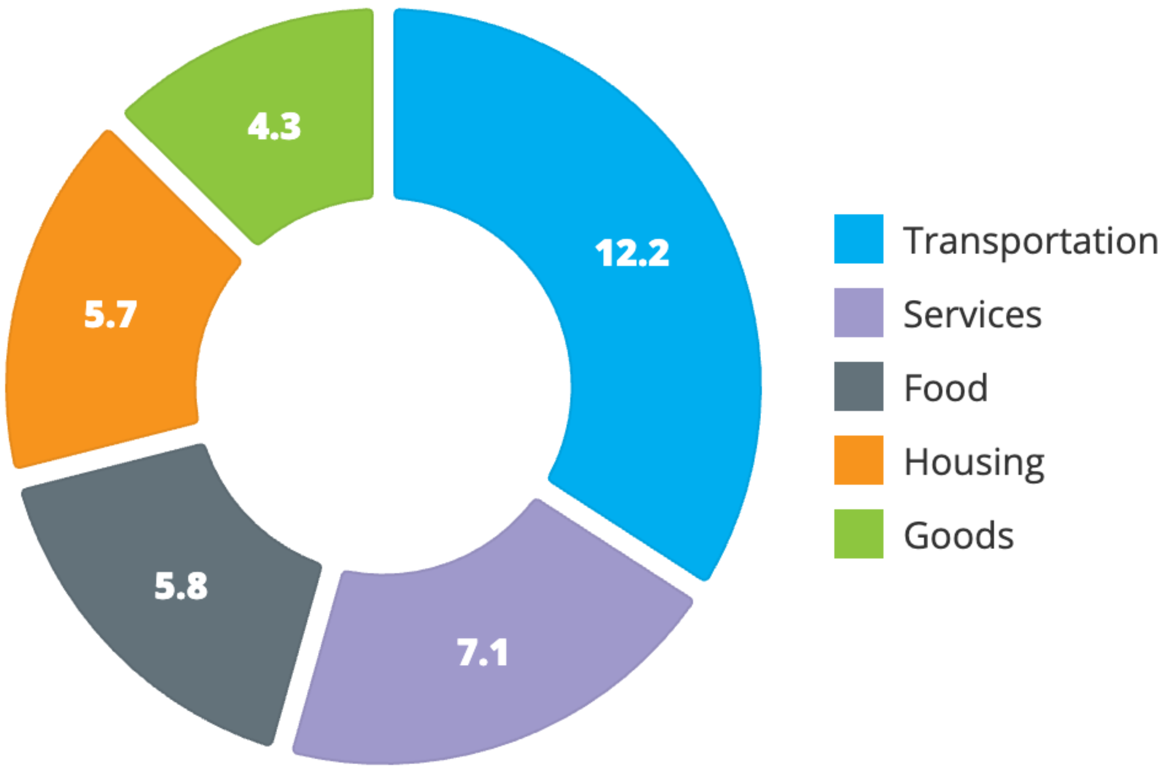


Figure 4 provides a detailed breakdown of these household level consumption-based emissions across 29 subcategories. Across household subcategories, the largest sources are gasoline (9.2 $MTCO_2e$), healthcare (3.9 $MTCO_2e$), electricity (2.4 $MTCO_2e$), dining out (1.8 $MTCO_2e$), and furnishings & appliances (1.7 $MTCO_2e$). Meat and dairy together are a combined 1.9 $MTCO_2e$, air travel is 1.6 $MTCO_2e$, and natural gas is 1.5 $MTCO_2e$. Together, these account for over two-thirds of the average household emissions. The full data is also broken out in Table 2, including both per household and communitywide totals, along with percentages by category and overall.

Figure 4. King County Average Household Consumption-Based Emissions by Category and Subcategory (2023)

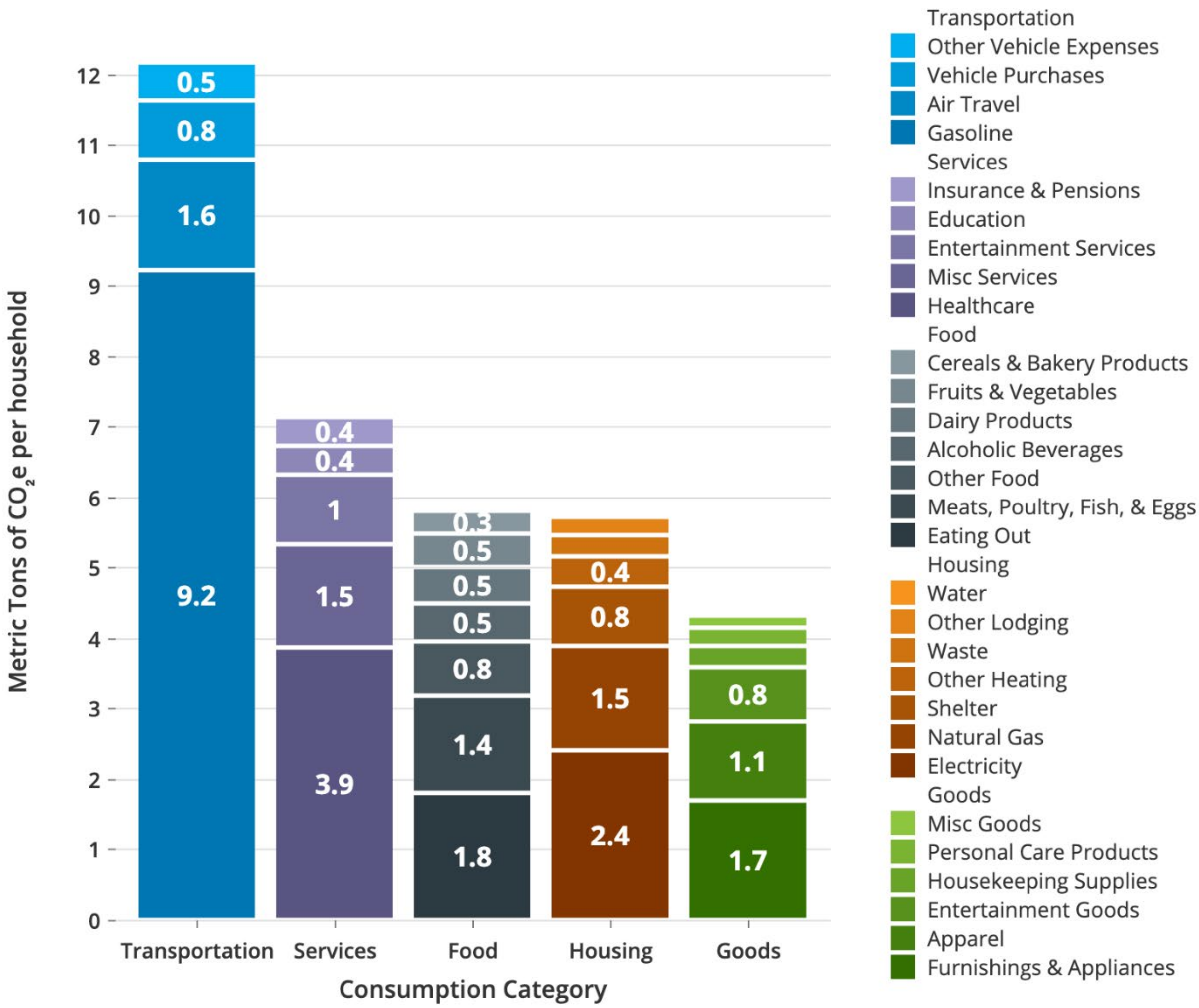


Table 2. King County Household Consumption-Based Emissions Breakdown (2023)

Category	Community-Wide Total ($MMTCO_2e$)	Per Household Emissions ($MTCO_2e$)	% of Category	% of Household Total
Transportation	**11.6**	**12.2**	**100%**	**34.6%**
Gasoline	8.7	9.2	75.7%	26.2%
Air travel	1.5	1.6	13.0%	4.5%
Vehicle purchases	0.8	0.8	6.9%	2.4%
Other vehicle expenses	0.5	0.5	4.4%	1.5%

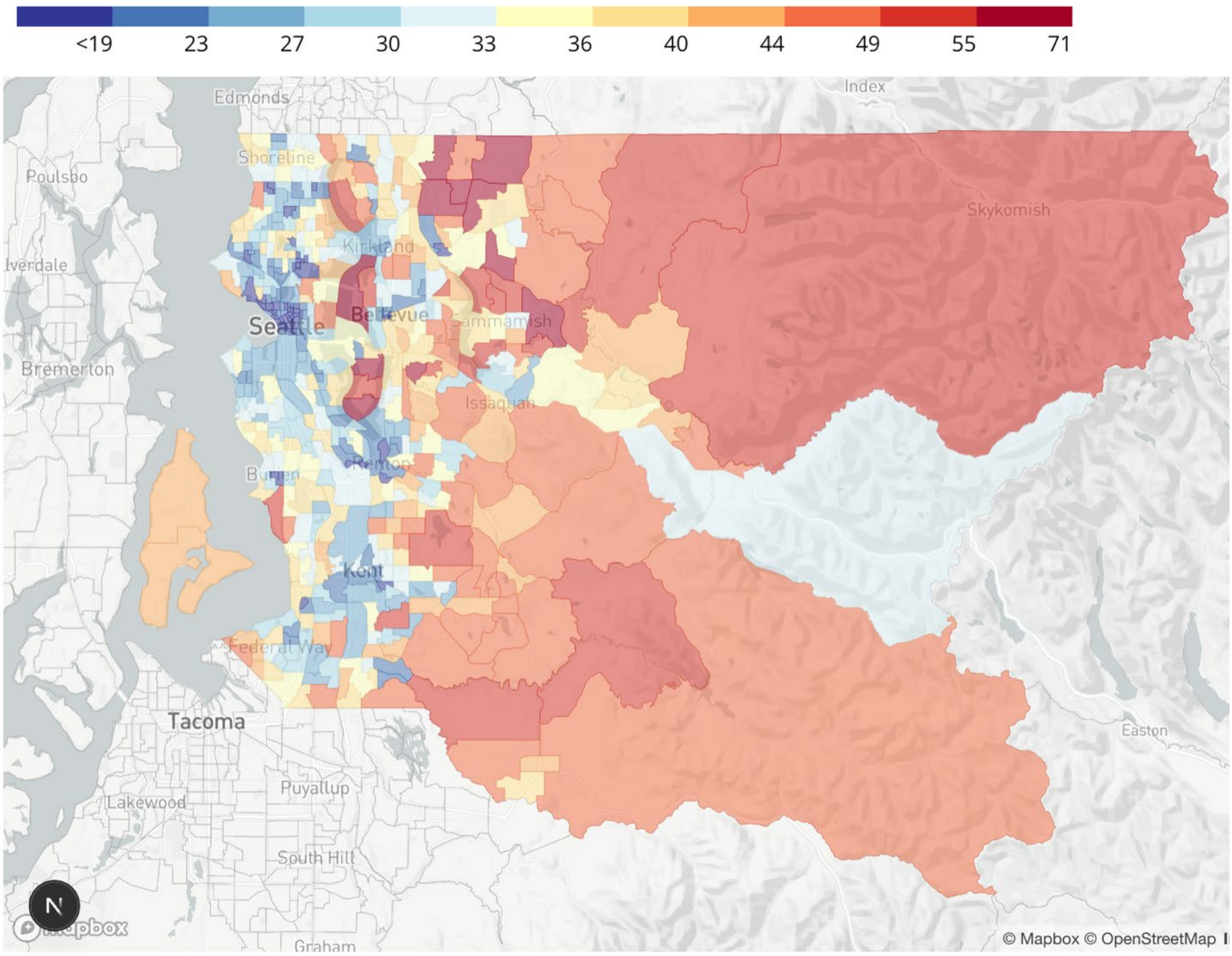
Category	Community-Wide Total ($MMTCO_2e$)	Per Household Emissions ($MTCO_2e$)	% of Category	% of Household Total
Services	**6.8**	**7.1**	**100%**	**20.3%**
Healthcare	3.7	3.9	54.1%	11.0%
Misc services	1.4	1.5	20.5%	4.2%
Entertainment services	0.9	1	13.7%	2.8%
Education	0.4	0.4	5.8%	1.2%
Insurance & pensions	0.4	0.4	5.8%	1.2%
Food	**5.5**	**5.8**	**100%**	**16.5%**
Eating out	1.7	1.8	31.1%	5.1%
Meats, poultry, fish, and eggs	1.3	1.4	23.6%	3.9%
Other food	0.7	0.8	13.3%	2.2%
Alcoholic beverages	0.5	0.5	9.4%	1.5%
Dairy products	0.5	0.5	8.8%	1.5%
Fruits & vegetables	0.5	0.5	8.3%	1.4%
Cereals & bakery products	0.3	0.3	5.4%	0.9%
Housing	**5.5**	**5.7**	**100%**	**16.3%**
Electricity	2.3	2.4	41.8%	6.8%
Natural gas	1.4	1.5	26.0%	4.3%
Shelter	0.8	0.8	14.3%	2.3%
Other heating fuels	0.4	0.4	7.7%	1.3%
Waste	0.3	0.3	5.0%	0.8%
Other lodging	0.2	0.3	4.5%	0.7%
Water	0.0	0.0	0.7%	0.1%
Goods	**4.1**	**4.3**	**100%**	**12.3%**
Furnishings & appliances	1.6	1.7	39.1%	4.8%
Apparel	1.1	1.1	26.0%	3.2%
Entertainment goods	0.7	0.8	18.2%	2.2%
Housekeeping supplies	0.3	0.3	7.1%	0.9%

Category	Community-Wide Total ($MMTCO_2e$)	Per Household Emissions ($MTCO_2e$)	% of Category	% of Household Total
Personal care products	0.2	0.2	5.5%	0.7%
Misc goods	0.2	0.2	4.0%	0.5%
Total	**33.4**	**35.1**	**100%**	**100%**

The household emissions component of the CBEI varies based upon six major household characteristics, as well as being influenced by local, real-world data including electricity emission factors and vehicle fuel economy. These factors drive changes at the neighborhood level across the region.

Figure 5 shows how these household emissions vary across the county, as a result of these household characteristics and other local factors (such as vehicle fuel economy and utility provider). For example, as shown on the map, households in downtown Seattle have lower average emissions (around 20-30 $MTCO_2e$ per household) than households in more suburban or rural areas of the county (around 35-70 $MTCO_2e$ per household). In downtown Seattle, households tend to have smaller homes, smaller household sizes, and are more likely to be renters. They have average or above-average incomes, but they own fewer vehicles, drive less, and use less electricity. Meanwhile, households in the southern portion of the county along I-5 tend to have lower incomes but have higher vehicle ownership or drive further distances than households in downtown Seattle, resulting in a mix of low (around 25-30 $MTCO_2e$) and average emission (around 30-40 $MTCO_2e$) neighborhoods. Meanwhile, households in the wealthier suburbs tend to have larger homes, higher incomes, and higher vehicle ownership, use more energy, and be more likely to be homeowners, all of which tend to increase consumption-based emissions. These neighborhoods more often have emissions around 40-70 $MTCO_2e$ per household.

Figure 5. Household Emissions by Neighborhood (Census Tract) ($MTCO_2e$, 2023)



Census tracts are colored according to the average per household emissions in the tract, independent of the number of households. Census tracts typically have around 2,500 to 8,000 people per tract, so areas with lower emissions per household could have more emissions overall if they have more households than areas with high emissions per household, but only a few households.

This pattern of consumption-based emissions is common across the country[6]. Dense urban areas typically have lower per household emissions, even at higher incomes. More suburban areas tend to have higher emissions, but low income rural areas also have lower emissions. In King County, lower household incomes are clustered in the southwest portion of the county along I-5, with a mix of higher and lower emissions. King County's emissions per household are comparable to other mixed regions with a dense urban core and suburban periphery – for example, Metro's recent CBEI for the Greater Portland tri-county region showed average household emissions of 35.2

[6] The New York Times, *The Climate Impact of Your Neighborhood, Mapped.* Accessed online Nov 2025. https://www.nytimes.com/interactive/2022/12/13/climate/climate-footprint-map-neighborhood.html

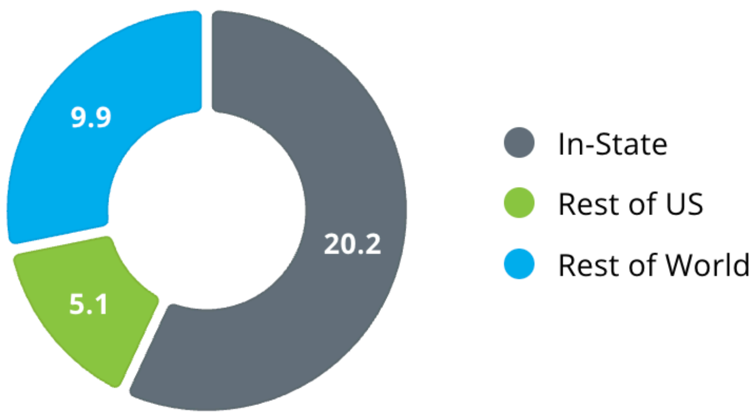
$MTCO_2e$ in 2023[7] (very close to King County's 35.1 $MTCO_2e$). Both Portland and Seattle have relatively low emissions per household, but the regional or countywide average is brought up by higher emission neighborhoods surrounding the urban center.

Household Emissions by Location of Emissions

Consumption-based emissions attributable to households in King County can occur anywhere in the world. Based on available USEEIO State Model data for Washington State, approximately 66% of King County's consumption-based emissions from households occur in-state, 15% in the rest of the US, and 20% internationally, as shown in Figure 6[8].

The location of emissions varies significantly by category, as shown in Figure 7. These breakdowns vary slightly across Washington, and may vary more significantly across states. Geographic breakdown estimates were not calculated for government or business investment emissions due to data limitations.

Figure 6. Household Emissions by Geographic Origin (2023)



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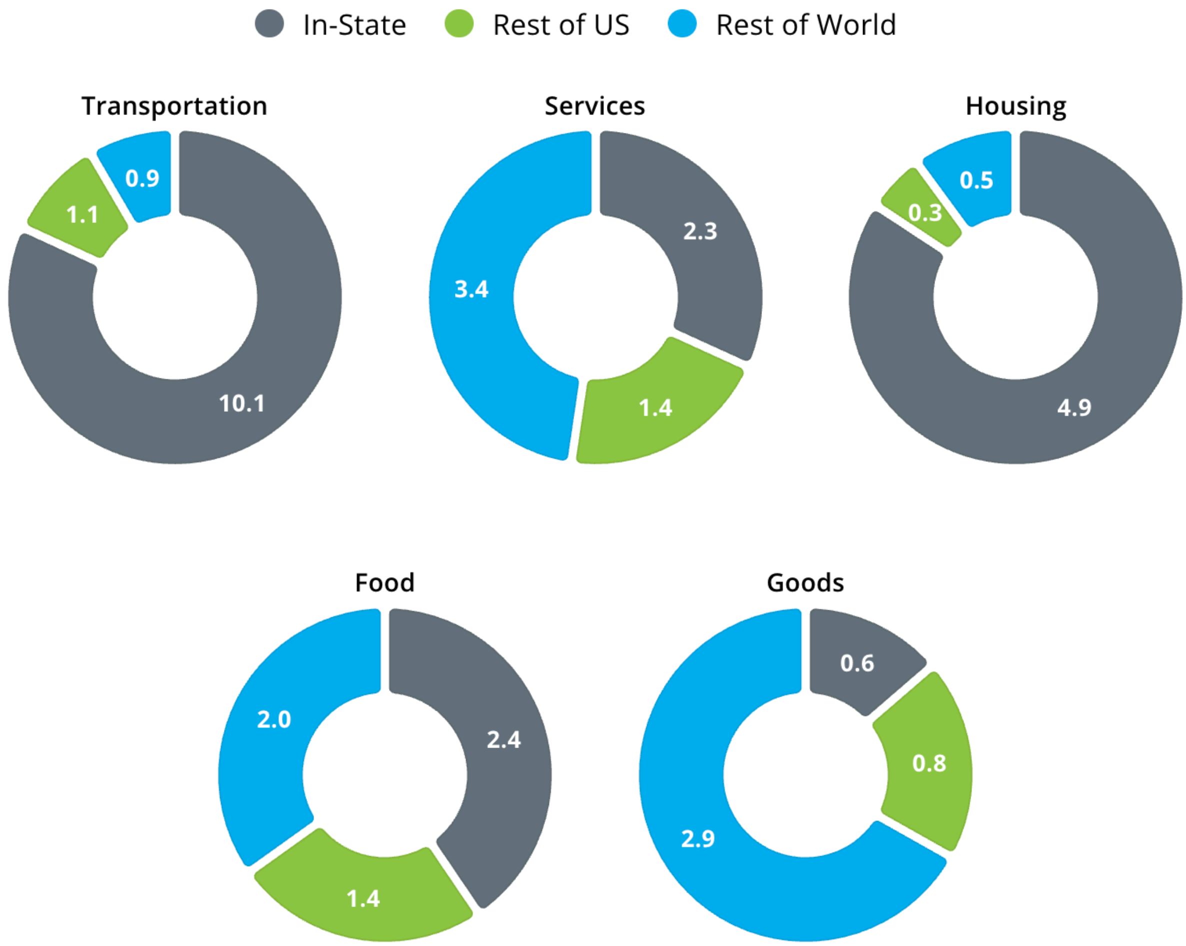
[7] Metro, *Greater Portland consumption-based emissions inventory*. Accessed Nov 2025. https://www.oregonmetro.gov/greater-portland-consumption-based-emissions-inventory

[8] This is estimated under a simplifying assumption that all emissions from gasoline and building energy use occur in-state, consistent with EPA estimates for Washington's statewide CBEI using USEEIO State Model data. See U.S. EPA, *Consumption-Based Greenhouse Gas Emissions Results for the State of WA for 2012-2019*: https://pasteur.epa.gov/uploads/10.23719/1531923/WA.html. Accessed June 2025.

Figure 7. Household Emissions by Geographic Origin by Category (2023)



While transportation and housing emissions are primarily in-state (as noted above, under a simplifying assumption), emissions from goods and services are tilted towards the rest of the world, while emissions from food are almost evenly split. For food, about 41% of emissions are in-state, 24% in the rest of the US, and 35% in the rest of the world. For services, about 32% of emissions are in-state, 20% in the rest of the US, and 48% in the rest of the world. Lastly, for goods, just 13% of emissions are in-state, with 19% in the rest of the U.S. and 68% in the rest of the world.

The emissions from household consumption that occur outside of Washington add roughly 50% to the in-state emission estimates. This highlights the importance of a consumption-based approach when considering and addressing greenhouse gas emissions: because GHGs have the same impact regardless of where they occur, solely looking at local emissions neglects the overall impacts of climate action through both local policies and individual household choices.

Household Emissions by Lifecycle Stage

The consumption-based emissions inventory uses lifecycle emission factors that account for the production, transport, sale, use, and disposal stages of goods and services demanded by final consumers. The analysis below breaks out the emissions associated with each lifecycle phase, by major consumption category and for certain select subcategories.

Each phase corresponds to a particular stage in the lifecycle of a good or service. Production-phase emissions reflect all emissions associated with producing a good or service prior to it being shipped off for sale, including resource extraction, processing, manufacturing, and other business activity like marketing and sales. Transport phase emissions are the emissions associated with moving a good or service to the location of wholesalers, retailers, or final consumers. Notably, transportation-related emissions that occur during the production of a good or service are allocated to the *production* phase of emissions. Transport phase emissions are solely the emissions involved in transporting a finished product to a point of sale or final customer. As a result, a good or service can involve significant transportation emissions in its production, but still have most emissions allocated to the production phase, if its ultimate consumer is only a short distance away – or comes to the site directly (such as locally produced products with input materials shipped from all over the world, or transportation services like sightseeing buses).

Sale phase emissions are the emissions generated by those wholesalers and retailers in storing and selling the good or service. Use phase emissions reflect activity by households directly, while waste phase emissions are the emissions associated with materials sent to the landfill.

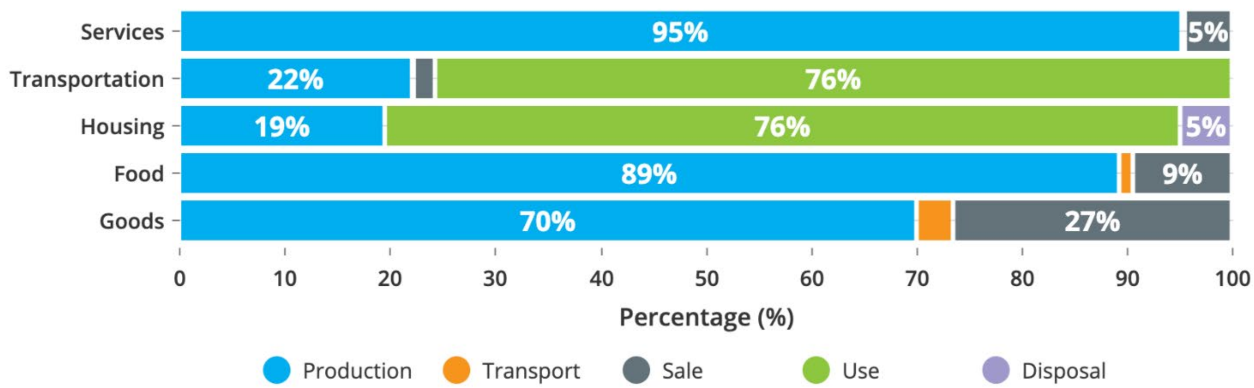
For food, goods, and services, most emissions occur in the production phase, while for transportation and housing, emissions primarily occur in the use phase (from gasoline and energy use).

In this CBEI, all waste emissions are allocated to the "Waste" subcategory within housing. Waste phase emissions are not broken out by source of waste (such as food waste versus paper products versus other goods).

Because of modern recycling and landfill emission reduction technology, the largest emissions impact from the waste phase are avoided emissions. Repairing, recycling, and composting materials that would otherwise go to landfill reduces emissions in the production phase (such as from extraction and processing of raw materials into products). These avoided emissions are already reflected in the CBEI in the emissions from purchased goods and services, although they are not calculated separately.

Figure 8 shows the share of emissions associated with each phase of the lifecycle – production, transport, sale, use, and disposal – for each major category in the household CBEI (lifecycle emission breakdowns are not available for government and business emissions due to data limitations).

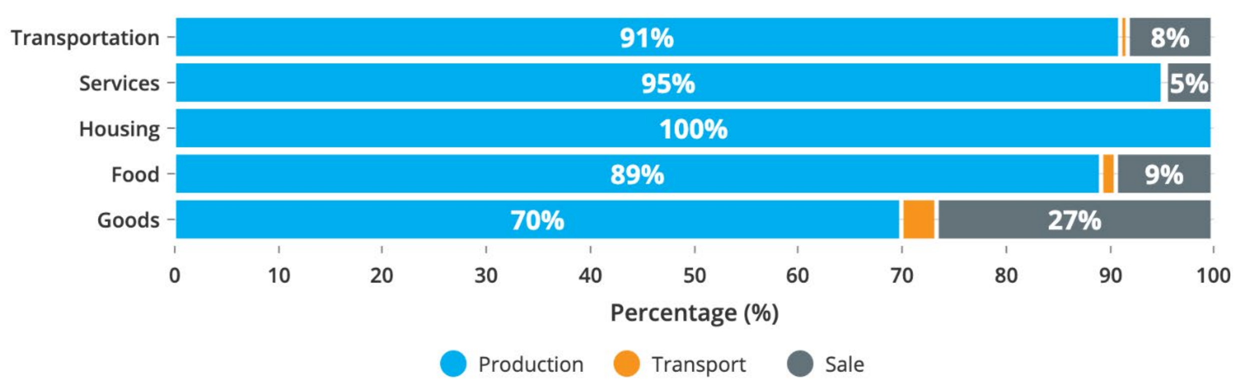
Figure 8. King County Household Emissions Breakdown by Lifecycle Stage (2023)



Household emissions from transportation and housing are dominated by "use phase" emissions - the burning of fossil fuels (such as gasoline or the methane in natural gas) for transportation or home heating energy. This "use phase" – primarily gasoline combustion and direct use of electricity and natural gas – makes up roughly 76% of household emissions from both transportation and housing emissions.

For food, goods, and services, use phase emissions are zero. These categories have some transport and sale emissions, but are overwhelmingly dominated by production emissions.

Figure 9. King County Household Pre-Purchase Emissions Breakdown (2023)



Pre-purchase emissions associated with Transportation (that is, prior to a consumer using a vehicle) are predominantly from production (91%). Some of these emissions are associated with the production of fuel (oil extraction and refining); most are from the production of vehicles and vehicle parts. Sale phase emissions mostly derive from the sale of gasoline and other transportation fuels.

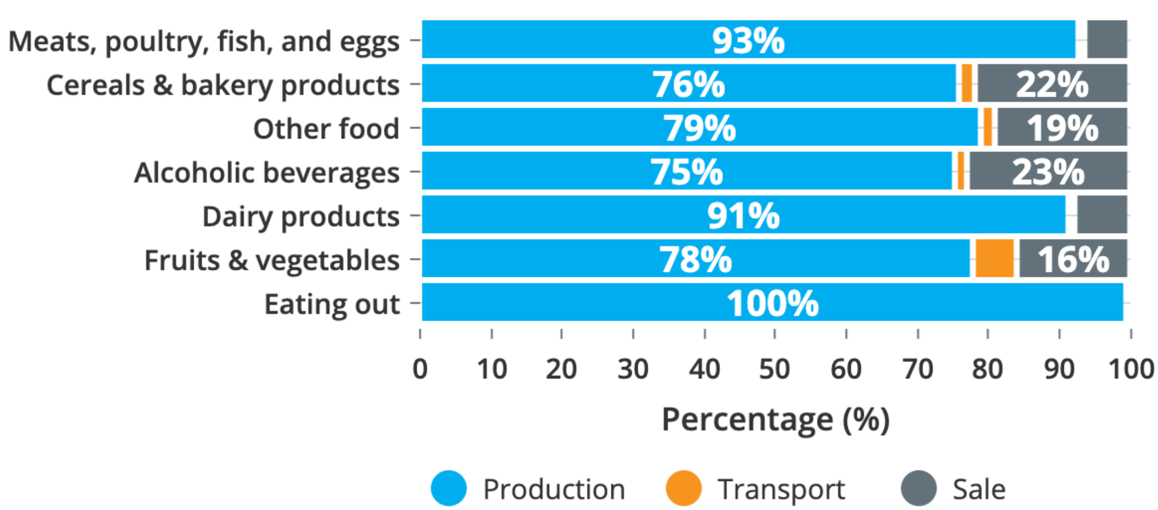
For housing, 100% of pre-purchase emissions occur in production. This is dominated by the production and construction of homes, apartments, and other lodging (including hotels).

For goods, about 70% of emissions come from production. About 4% of emissions from goods comes from transportation, and 27% comes from sale (wholesale and retail combined).

Like housing, pre-purchase emissions from services are overwhelmingly (95%) from production. Services are primarily made up of activities like healthcare, education, entertainment, and various financial services. In the CBEI, transportation and sale phases are associated with businesses other than the producer of the service directly; however, most services are marketed and sold directly to consumers without requiring third party transport or retail. For instance, a plumber might drive to a job site directly; in this case, the driving emissions are associated with the production phase of the plumbing service. Similarly, a transportation service such as a sightseeing tour or ambulance ride would be associated with the production of the service itself, rather than a third party transporting the service to a consumer.

For food, roughly 89% of emissions occur in production. Food emissions primarily come from application of nitrogen fertilizers and enteric fermentation (methane released from digestion by cows and other livestock). These emissions significantly outweigh the emissions associated with transportation or sale of food. Figure 10 provides a detailed breakdown by subcategory within Food.

Figure 10. Pre-Consumer Food Emissions Breakdown



For all food sub-categories, over 75% of emissions come from production. For alcoholic beverages and cereals and bakery products, production emissions account for roughly 75-76% of emissions. Fruits and vegetables and other food have roughly 78-79% of their emissions from production, while meat and dairy products have over 91% of their emissions from production. 100% of emissions associated with eating out are from production. Within all food sub-categories, transportation emissions are overwhelmingly dominated by truck transport; however, sale emissions are the primary secondary driver of emissions, accounting for 6-23%, depending on the subcategory.

2023 Government and Business Investment CBEI Results

Government emissions derive from general government procurement and spending on goods and services, as well as government investments in structures, equipment, and intellectual property.

The communitywide emissions from all government consumption and investments in King County was estimated at 6.1 $MMTCO_2e$. Of this total, state and local government made up about 91% of emissions, almost entirely from consumption of goods, services, and energy. This includes all goods and services purchased for general short-term operational needs, such as food, office supplies, etc., as well as direct emissions associated with gasoline and diesel, electricity, and natural gas usage.

Structures emissions primarily consist of the emissions associated with producing and transporting the materials used in the construction of buildings and infrastructure, while equipment is purchases of objects with a multi-year lifespan such as furniture, computers, and vehicles. Lastly, intellectual property includes the emissions associated with activities and contracts which generate novel research, analysis, reports, or other material that can be copyrighted or patented.

These emissions are broken out by state and local (combined), federal defense, and federal non-defense, based on the USEEIO data provided by U.S. EPA. Emissions are calculated at the state level and allocated to counties in King County based on each county's relative share of statewide employment for each government sector.

Table 3. Government Emissions Breakdown in King County ($MMTCO_2e$, 2023)

Government Sector	Goods, services, & energy use	Structures	Equipment	Intellectual Property	Total
State & Local	4.1	1.0	0.2	0.05	5.3
Federal Non-Defense	0.6	0.05	0.02	0.1	0.8
Federal Defense	0.04	0.00	0.01	0.00	0.04
Total	**4.7**	**1.0**	**0.2**	**0.2**	**6.1**

Business Investment Emissions

Under the consumption-based framework, businesses are generally considered intermediate economic producers. From this perspective, businesses' operating emissions are generally allocated to the final consumer (household or government) of the businesses' output. This includes both direct emissions from the businesses' use of fossil fuels and energy, as well as indirect emissions from business operations including purchased goods and services, food, and air travel.

In the CBEI, businesses are considered the final consumer when it comes to their long-term investments in capital assets like structures, equipment, intellectual property, and changes in inventory (e.g. warehouse stock).

Business sectors are broken out by North American Industrial Classification System (NAICS) code and organized at the two-digit sector level[9]:

- NAICS 11: Agriculture, Forestry, Fishing and Hunting
- NAICS 21: Mining, Quarrying, and Oil and Gas Extraction
- NAICS 22: Utilities
- NAICS 23: Construction
- NAICS 31: Manufacturing – Food, Beverage, Textile, Apparel, Leather
- NAICS 32: Manufacturing – Wood, Paper, Chemical, Plastic, Mineral
- NAICS 33: Manufacturing – Metal, Machinery, Computers, Electronics, Transportation, Furniture, Miscellaneous
- NAICS 42: Wholesale Trade
- NAICS 44: Retail Trade – Motor Vehicles, Furniture, Electronics, Food, Health, Gas, Clothing
- NAICS 45: Retail Trade – Sporting Goods, General Merchandise, Miscellaneous
- NAICS 48: Transportation and Warehousing – Air, Rail, Water, Truck, Transit, Pipeline
- NAICS 49: Transportation and Warehousing – Delivery and Warehousing
- NAICS 51: Information Services
- NAICS 52: Finance and Insurance
- NAICS 53: Real Estate and Rental and Leasing
- NAICS 54: Professional, Scientific, and Technical Services
- NAICS 55: Management of Companies and Enterprises
- NAICS 56: Administrative and Support and Waste Remediation Services
- NAICS 61: Educational Services
- NAICS 62: Health Care and Social Assistance
- NAICS 71: Arts, Entertainment, and Recreation
- NAICS 72: Accommodation and Food Services
- NAICS 81: Other Services (except Public Administration)
- NAICS 99: Non-classifiable Establishments

In this report, these are aggregated into goods industries (NAICS 11-33), transportation and sale (NAICS 42-49), and services (NAICS 51-99).

In King County in 2023, roughly 35% of business investment emissions were associated with structures (2.7 $MMTCO_2e$), 34% with equipment (2.7 $MMTCO_2e$), and 32% with intellectual property (2.5 $MMTCO_2e$). Businesses were estimated to draw down inventory stockpiles in 2023, leading to an emissions reduction of roughly 1% (due to

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[9] The underlying USEEIO data includes 73 summary-level industry codes at the two, three, or four-digit level for different industries. This CBEI analysis rolls up three- and four-digit codes into their parent two-digit codes for ease of comparison.

the consumption of this accumulated inventory by households). Table 4 provides a breakdown of these emissions by aggregated industry sector.

Table 4. King County Business Investment Emissions Breakdown ($MMTCO_2e$, 2023)

Sector	Structures	Equipment	IP	Inventory	Total
Services (51-99)	2.0	1.6	2.4	-0.0	6.0
Goods (11-33)	0.4	0.7	0.0	-0.0	1.1
Transportation and Sale (42-49)	0.3	0.4	0.1	-0.0	0.7
Total	**2.7**	**2.7**	**2.5**	**-0.1**	**7.9**

Emissions over time

Since 2007, King County's total consumption-based emissions have increased by about 2.1 $MMTCO_2e$, or 5%. Most of this 7% increase was driven by an increase in total emissions from households, as a result of significant (24%) growth in the number of households.

King County's per household emissions (35.1 $MTCO_2e$) are about 4% lower than Washington's statewide average (36.5 $MTCO_2e$). As a result, each household located in King County avoids about 1.4 $MTCO_2e$ per household compared to being located elsewhere in the state. King County's growth in households since 2007 has avoided roughly 2 $MMTCO_2e$ that would have been generated had those households located elsewhere in Washington state.

King County's emissions per household have decreased by about 6.5 $MTCO_2e$ per household, or 19%, since 2007, driven by reductions in transportation (-1.9 $MTCO_2e$, -16%), goods (-1.9 $MTCO_2e$, -43%), and food (-1.6 $MTCO_2e$, -28%), along with smaller reductions in housing (-0.9 $MTCO_2e$, -15%) and services (-0.2 $MTCO_2e$, -3%).

Transportation emission reductions have come from a combination of reductions in vehicle miles traveled (VMT) and improvements in vehicle fuel economy. Since 2007, VMT has declined by about 6%, due to falling vehicle ownership, declines in driving to work, increasing numbers of seniors per household (with declining numbers of children, youth, or adults), and increasing density. At the same time, vehicle fuel economy has improved by about 10%. Similarly, emissions from the housing category have declined largely to 13% reduction in emissions intensity, along with a 10% reduction in electricity usage per household over time. Natural gas usage has declined by nearly 27% since 2007.

For food and goods, most of the reductions have been driven by economy-wide reductions in the emission intensities of food, goods, and services. Some subcategories, like cereals and bakery products, personal care products, and other lodging, have seen emissions per dollar fall by as much as 50%. Major subcategories, like meat and dairy, have seen domestic emissions fall by 30-40% per dollar of production. Healthcare emissions have declined by roughly 28% on a per-dollar basis, while emissions from furnishings and equipment fell by 49% per dollar. However, this only holds true for items produced in the U.S. – items produced in the rest of the world have not seen the same magnitude of reduction, and in some cases (including meat) have actually seen increases in emissions per dollar.[10] In the US, this is a result of successful policy efforts to reduce the use of fossil fuels – U.S. nationwide emissions peaked in 2005 and have declined by roughly 20% since. However, emissions in the rest of the world have continued to grow.

While the emission intensity of services has decreased, King County households have seen significant growth in income and education, leading to increased demand for services. Since 2007, real (inflation-adjusted) average household income has increased by 16%, from about $97,000 to around $113,000 (in constant 2012 dollars). Nominal average household income has grown from about $87,000 in 2007 to around $149,000 in 2023[11]. Figure 11 shows these changes over time in both real and nominal household income.

[10] Based on EcoDataLab data derived from USEEIO Supply Chain Emission Factors by NAICS-6 codes. All emissions per dollar metrics are in constant dollars, accounting for subcategory-specific changes in the consumer price index and are not a result of inflation.

[11] The CBEI uses custom average household income estimates derived from U.S. Census data that may under-estimate the true average household income. The relationships between household spending and emissions do not remain constant at very high incomes, so the CBEI methods ignore household incomes above $300,000.

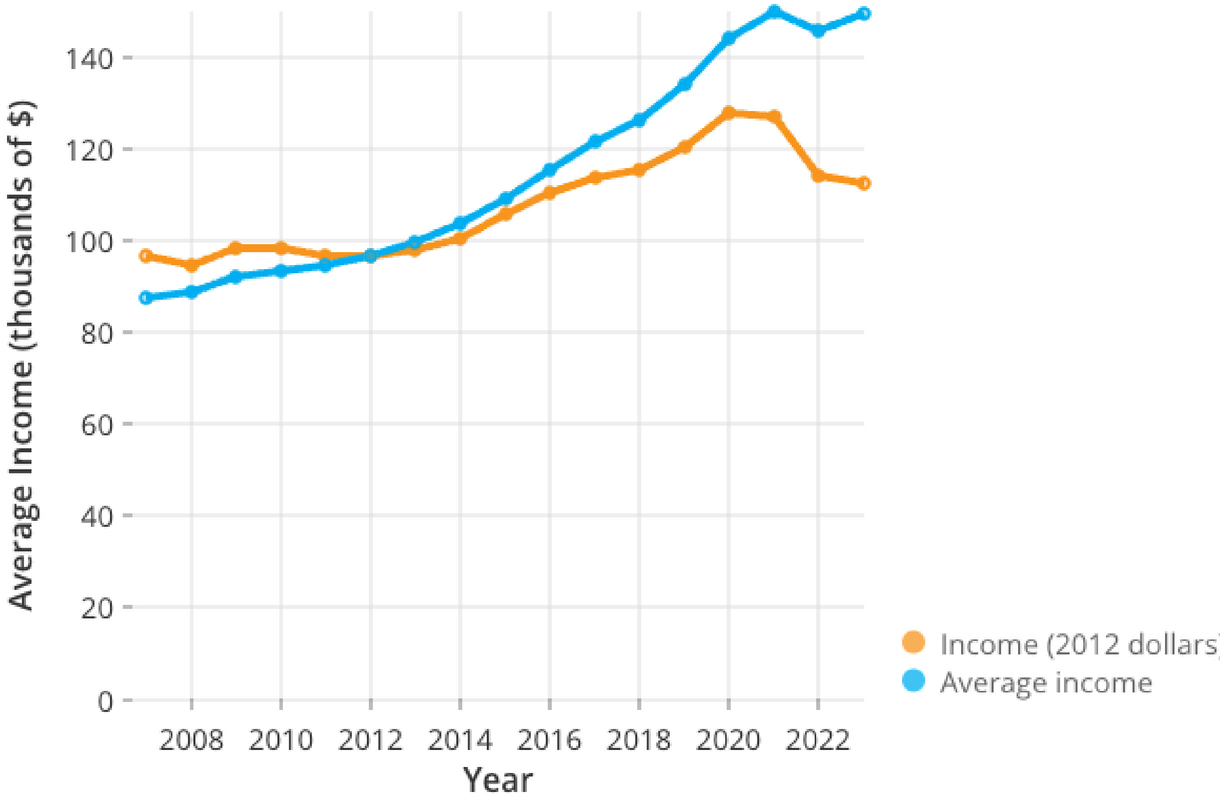

Figure 11. King County Average Household Income Over Time

At the same time, King County has also become significantly more educated. In 2007, 45% of households had at least one person with a college degree or higher; by 2023, over 60% had a college education. Higher education tends to correlate with more spending on services and food away from home. In addition, declining home ownership (from 61% to 56%) has also helped shift spending away from goods and furnishings towards services. Figure 12 shows the changes in educational attainment and home ownership over time.

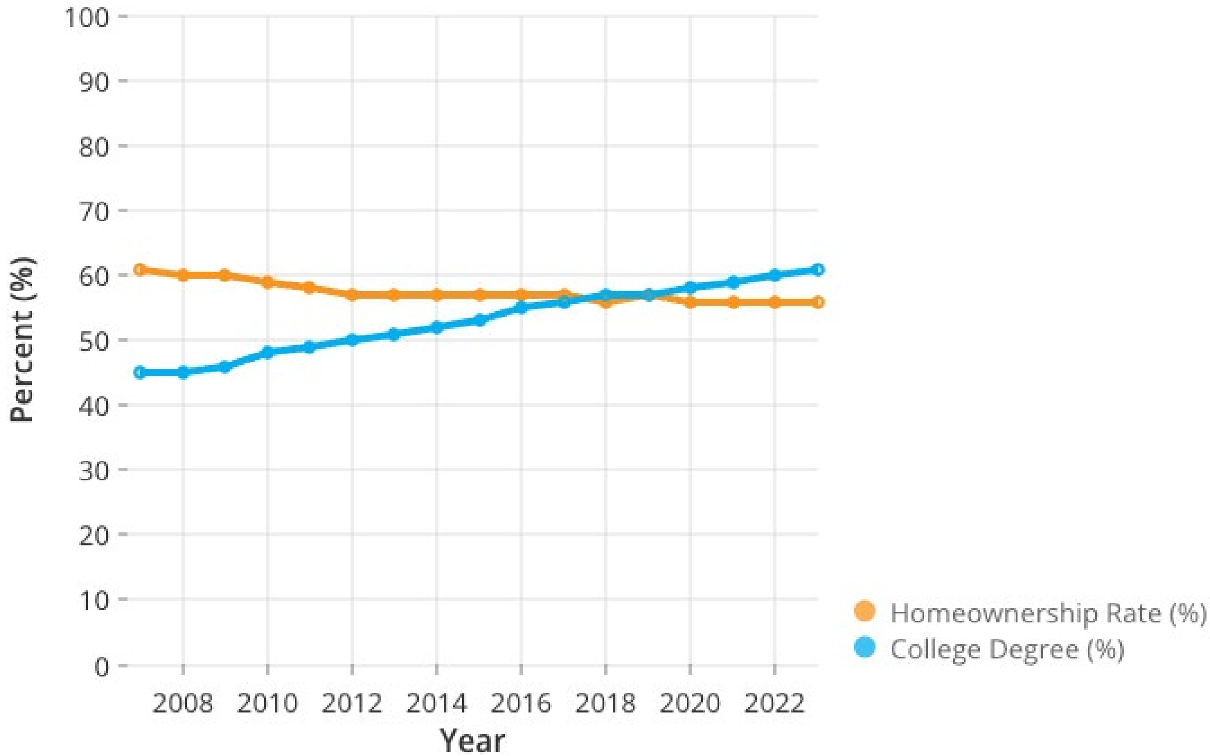

Figure 12. King County Educational Attainment and Home Ownership Over Time

Higher income generally correlates with higher spending, while changes in education and home ownership shift spending between categories. However, reductions in the emissions intensity of goods and services have more than offset this growth in spending (although just barely for the Services category). Overall, households in King County generate significantly fewer emissions than they did in 2007, but King County's household growth has meant that total communitywide emissions have increased slightly since 2007.

Conclusion

King County's consumption-based emissions of 47.3 $MMTCO_2e$ primarily derive from household consumption (33.4 $MMTCO_2e$, or 71%), with smaller portions from government (6.1 $MMTCO_2e$, or 13%) and businesses (7.9 $MMTCO_2e$, or 17%). Gasoline, building energy use (electricity and natural gas), building construction, meat and dairy, and furnishings and equipment are some of the largest sources of emissions. Most emissions either derive from the use of fossil fuels and energy, or from the production of food, goods, and services. Most use-phase emissions occur in-state, while most production-phase emissions occur in the rest of the U.S. or rest of the world.

King County's emissions per household have declined significantly since 2007, driven by a combination of declining emissions intensity for food, goods, and services; reductions in energy and automobile usage; and improvements in fuel economy and energy efficiency.

This CBEI supports the 2025 King County Strategic Climate Action Plan (SCAP), including outcomes envisioned in the *Design Out Waste* flagship and actions in the *Circular Economy* focus area. King County's goal for a circular economy is to achieve zero waste of resources by reducing consumption and waste generated, and increasing reuse, recycling, and composting. The County is committed to achieving a circular economy where waste is minimized, and materials remain in use longer. By highlighting the embodied emissions in the goods and services consumed in the county, this CBEI report shows the magnitude of emission reduction opportunities available from reducing or avoiding waste and increasing reuse.

Appendix A – Community-wide Consumption-based Emissions Inventory Methodology

General Overview

The community CBEI does not directly measure individual households' consumption or behavior. Instead, a model (a series of complex calculations) is used to estimate consumption of goods and services and associated emissions. The King County CBEI uses a combination of real-world consumption or emissions data where available along with predictions based upon demographic, regional, and national averages.

Household CBEI

EcoDataLab's CBEI approach uses three model components to build the household portion of the inventory: a vehicle miles travelled (VMT) model, a household energy model, and a consumption model. The consumption model is built of separate sub-models for each subcategory of consumption, excluding gasoline and household energy use. Each model and sub-model follows the same general formula, described below.

1) Select a survey

First, a nationwide survey, conducted by the U.S. federal government, that focuses on an important element of the inventory is selected. The U.S. models are built using the Consumer Expenditures Survey (CEX)[12], the National Household Travel Survey (NHTS)[13], and the Residential Energy Consumption Survey (RECS)[14].

These surveys are used to build the full suite of models for the CBEI. CEX provides data used to model all sub-categories of consumption except for gasoline and home energy use. NHTS provides data for the vehicle miles travelled model, which translates into gasoline usage. RECS provides data for the home energy use models including electricity, natural gas, and other heating fuels.

2) Identify key household characteristics

Next, household characteristics are identified which are both included in the survey and for which nationwide data from the U.S. census and other data sources are available. These data include variables like household size, income, vehicle ownership, etc. Geography, climate, and other relevant data are also included where applicable. For a complete list of variables in each model, see Model Input Variables below.

3) Build a predictive model

With the nationwide survey and selected household and geographic characteristics, a computer program is run to identify how strongly each of those household characteristics correlate with the survey results. This technique is called multiple linear regression, a statistical method often used in machine learning. The computer sees

[12] https://www.bls.gov/cex/
[13] https://nhts.ornl.gov/
[14] https://www.eia.gov/consumption/residential/

many input data (the household and geographic characteristics) and learns how to predict what the outcome will be (the survey result). The computer then provides an equation that takes each of those household and geographic characteristics and produces an estimated result.

A single linear regression might take this form:

$$y = mx + b$$

where y is the survey result (dependent variable), x is the household and geographic characteristics (independent variable), m is the computer's predicted correlation between x and y (slope), and b is a fixed value that adjusts for any underlying base discrepancy between x and y when x is equal to 0 (intercept).

In multiple linear regression, the equation takes on a more complex form:

$$y = m_1x_1 + m_2x_2 + m_3x_3 + ... + b$$

where in this case, each x (x_1, x_2, x_3, etc.) is a different household or geographic characteristic, with its own unique correlation (m_1, m_2, m_3, etc.), that together add up to produce the overall result. The number of x variables depends on the sub-model and available data. Almost all sub-models use at least six variables (…x_6), with some using a dozen or more to reach the most accurate prediction possible.

In addition, many of the values considered do not scale linearly. Instead, the models often look more like this:

$$\ln(y) = m_1x_1 + m_2*\ln(x_2) + m_3x_3 + ... + b$$

where the survey result might actually be scaled as a natural log (ln) variable, and some of the household and geographic characteristics are also calculated using its natural log (or sometimes both its ordinary and natural log values). This generally occurs in cases where there are nonlinear effects from household characteristics, and smaller values have different implications than larger values. For example, a household of two is typically two adults, whereas a household of three typically includes a child, which can significantly change consumption patterns. Similarly, consumption patterns based on income change significantly once basic needs are met and "luxury goods" start being consumed.

4) Run the model using local data

After these multivariate linear regression models are built (see above), local data is then collected to be used in the model. These data consist mostly of census and climate data, from federal sources including the U.S. Census Bureau, the National Oceanic and Atmospheric Administration (NOAA), but also include things like energy prices, inflation rates, fuel economy, and emission factors from sources including the Energy Information Administration (EIA), the Bureau of Labor Statistics (BLS), the Department of Energy (DOE), and the Environmental Protection Agency (EPA). Those values are transformed to fit the required inputs to the model, and then the model is run with that local data as the independent (x) variables in the model.

Running these models produces dollars of household expenditures for most sub-categories of consumption, except for the VMT and household energy models, which produce estimated miles travelled by private automobile and energy usage (in kWh of electricity, therms of natural gas, and BTU of other heating fuels).

5) Calculate emissions

After calculating consumption using the models, emissions are calculated. Most consumption emissions are calculated using the U.S. EPA's U.S. Environmentally Extended Input-Output Model (USEEIO)[15], which bridges the gap between consumption (dollars) and emissions (grams of CO_2e). The USEEIO model includes data on emissions by sector and supply chain stage, allowing for differentiation between emissions associated with production, transport, wholesale, and retail, for all U.S. emissions (emissions occurring outside the U.S. are not included). To account for emissions associated with fixed capital investments (e.g. buildings and infrastructure construction, excluding residential construction), all subcategory emission factors are increased by roughly 13 per cent, in line with the overall economy-wide share of emissions attributable to fixed capital. (Research is underway to better allocate fixed capital emissions to the associated subcategory)

In the standard U.S. approach, electricity emissions are calculated using EPA's Emissions and Generation Resource Integrated Database (eGRID) emission factors, detailed at the ZIP code level and then scaled to any geography. For all other direct consumption of fuels (natural gas / methane, gasoline, etc.), the latest Intergovernmental Panel on Climate Change (IPCC) estimates of global warming potential (GWP)[16] and best available academic literature are used to estimate lifecycle emissions. (IPCC GWP values are commonly used across the majority of emissions reporting protocols, such as the Global Protocol for Community-Scale GHG Inventories[17] and the Local Government Operations Protocol[18]). This includes fugitive emissions (e.g. undesired leaks of greenhouse gases) and non-CO_2 GHG emissions, as well as any additional climate forcing effects from other emissions (such as particulate matter or contrails).

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[15] https://www.epa.gov/land-research/us-environmentally-extended-input-output-useeio-models
[16] IPCC AR6 Chapter 7: Supplementary Material. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_07_Supplementary_Material.pdf
[17] https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities
[18] https://ww2.arb.ca.gov/local-government-operations-protocol-greenhouse-gas-assessments

When working with local jurisdictions, these national or grid average emission factors are replaced with the best available local data.

6) Make final adjustments to consumption estimates

While the multiple linear regression models help to estimate consumption, the model does not perfectly resemble reality. These discrepancies are adjusted by comparing the model's predicted results with real-world data wherever available, and scaling the model outputs accordingly where real-world data isn't available.

To achieve this, the model results are compared with the actual results for the most granular level of data available. This can be national-level data (in the case of surveys), state- or province-level data (in the case of transportation), or locality-level data (in the case of energy or water consumption). For cases where real-world data is available at the geographic scale of interest, the real-world data is used instead; otherwise, the model is run at the same geographic level at which data is available and uses that to create a scaling factor in order to correct the locally modeled data. For example, modeled state-level energy use is compared with real state-level energy data, and then used to generate a scaling factor to adjust each census tract's modeled energy use. This scaling correction is usually on the order of 10 percent.

Model Input Variables

The household consumption models use the following six variables: household size, average income, vehicle ownership, home ownership, share of household respondents with a bachelor’s degree or higher (educational attainment), and number of rooms (home size). All six of these variables are derived from the American Community Survey (ACS) data, provided by the U.S. Census.

The household vehicle miles traveled model uses the same six variables as household consumption model, along with 10 additional variables. These are: commute time to work, drive alone to work, number of homes per square mile, number of employed people per square mile, employed people per household, family status, children per household, youth per household, adults per household, and Census region. All of these variables are derived from ACS data.

The household energy models use nine variables: household size, average income, home ownership, home size, detached home status, heating and cooling degree days, statewide average price of electricity, statewide average price of natural gas, and census division. Heating and cooling degree days are provided by the National Oceanic and Atmospheric Administration (NOAA), while energy prices are provided by the Energy Information Agency (EIA). The other variables are derived from ACS data.

Household incomes are adjusted for inflation using the BLS’ consumer price index (CPI) for all urban consumers. CPI-adjusted incomes are used in each model (consumption, vehicle miles travelled, and energy), based upon the year of the model’s base survey. For instance, the latest VMT model is based on 2017 NHTS data, so modeled transportation estimates use the 2017 inflation-adjusted household income.

The household consumption estimates use USEEIO v2.0 emission factors. The government and business emissions estimates use USEEIO State Model emission factors, using the v1.1-GHG models.

King County Assumptions and Adjustments

For the King County CBEI, the following real-world data adjustments were made when calculating household emissions:

- County-level average residential electricity usage data was used.
- Regional average residential natural gas usage data was used.
- Utility-specific electricity emission factors were used for Puget Sound Energy and Seattle City Light for 2014-2022. Due to data limitations, 2023 electricity emission factors were assumed to be the same as 2022.
- Local passenger vehicle fuel economy data was used for every census tract and for the county as a whole.
- Statewide average household waste emissions data was used on a per capita basis for every census tract and the county.
- 2015 county-level household water data from USGS was assumed to remain constant.

Government and Business Emissions

Government and business emissions are estimated based on the USEEIO State Model data.

The Use table (tab "U") in the State Model dataset for each year breaks down in-state final demand for government consumption, structures, equipment, and intellectual property by federal defense, federal non-defense, and state and local government (combined), along with private (business) non-residential investments in structures, equipment, intellectual property, and changes in inventory. These final demand amounts are detailed by industry, broken out among 72 different USEEIO codes (which either reflect 2-digit NAICS codes, or one or more 3- or 4-digit NAICS codes).

These final demand amounts are multiplied by the respective emission factors from the Direct + Indirect Impact Factor table (tab "N") to generate the statewide aggregate emissions by final consumer and sector. As USEEIO State Models only span 2012-2020, statewide emissions are extrapolated forward and backwards to 2023 and 2007 using linear regression (capped at 3% per year).

These emissions are then scaled to the county level using employment data from the Quarterly Census of Employment and Wages (QCEW), provided by the Bureau of Labor Statistics (BLS), along with Department of Defense (DOD) employment data to scale defense spending. No national dataset on where government expenditures occur at the sub-state level is available. Emissions for federal, state, and local governments are scaled to counties based upon employment in order to reflect policymaking considerations: the locations where government employees work is generally reflective of where decision-making occurs. Employment-based scaling of statewide emissions reflects the magnitude of emissions within the sphere of influence of local decisionmakers.

For business emissions, QCEW detailed county-level breakdown tables provide annual employment numbers at the 2-, 3-, and 4-digit NAICS code level. Suppressed values are estimated using the unallocated employment numbers from one level of aggregation higher, divided evenly across all suppressed values. Employment is aggregated to the USEEIO code level. For intellectual property and changes in inventory, emissions are scaled by county based on each county's share of that USEEIO code's statewide employment. For structures and equipment, the Annual Capital Expenditure Survey (ACES) data is used to determine national average allocations of capital expenditures by USEEIO code, which is subsequently scaled and normalized by state for each state's relative breakdown of employment by USEEIO code. Every industry is assumed to consume the inputs to final demand for structures and equipment equally. Emissions are then scaled to counties based on each county's share of that USEEIO code's statewide employment. USEEIO codes are then aggregated to 2-digit NAICS codes to estimate emissions by industry sector.

Federal and state and local employment estimates are available at the annual high-level summary level. DOD data, provided by the Office of Local Defense Community Cooperation (OLDCC), provides county-level defense personnel numbers for 2018-2023. Suppressed values are assumed to be the maximum level (10 employees). For years prior to 2018, Defense Manpower Data Center (DMDC) data on statewide defense employment is used to scale OLDCC county-level personnel backwards to 2008. Counties with no personnel in 2018 are assumed to have zero personnel in prior years as well. County-level civilian defense personnel are subtracted from total federal civilian employment from QCEW before county-level federal nondefense emissions allocations are made. Total defense personnel are used to estimate each county's share of statewide federal defense emissions, and total state and local employment is used to estimate each county's share of statewide total state and local emissions.

Technical Details

The Consumer Expenditures Survey (CEX) is the only annual national survey of household consumption in the United States. Within the CEX, there are a total of 95 categories and subcategories of expenditures for everything U.S. households consume, including detailed breakdowns of food, utilities, home construction, transportation, household goods and services.

The CEX is used as the initial basis for our consumption models across all categories of expenditures. Because the smaller subcategories have more uncertainty and error associated with them, EcoDataLab's models are generally developed at either first- or second-tier category level across the CEX dataset. After running the models at the local level, local consumption estimates are normalized to national data. This is done by using a scaling factor based upon the ratio of national modeled results to real-world national survey results, across each category of consumption.

CEX categories are then mapped to Personal Consumption Expenditures (PCE) developed by the Bureau of Economic Analysis (BEA). Each PCE maps to one or more sectors of the U.S. economy, and each sector has associated full supply chain emissions available through the U.S. EPA's USEEIO model. BEA's Detailed PCE Bridge Tables (available for 2007, 2012, and 2017) allow for assigning emissions to production (cradle-to-gate), transportation to market, and wholesale and retail stages. Further detail is provided through BEA's IO Use After Redefinitions tables, which allow for breaking down the transport to market into respective shares from air travel, truck transportation, water transport, rail transport, and other modes, while the BEA Summary PCE Bridge Tables allow for interpolation between 2007-2012, 2012-2017, and extrapolation from 2017-2023.

Custom emission factors (grams CO_2e per dollar of expenditure) are then created based on the detailed mapping of sectors, PCE and CEX categories. This converts average U.S. household expenditures to total U.S. emissions, broken down by each CEX category and in total.

The lifecycle emission factors from USEEIO are available for 2010-2016, 2018, and 2022. To calculate emissions in other years, they are adjusted backwards and forwards in time as needed using linear regression with a 3% annual change restriction. Prior to calculating emissions, all modeled and real-world household expenditures are also normalized to 2012 U.S. dollars using the category-specific Consumer Price Index (CPI) or Chain-Type Price Index (from BEA) for each category.

For international emissions, the share of emissions from international purchases is calculated using the USEEIO State Model data for 2012-2020 by finding the difference between the total Use table (tab U) and domestic-only Use table (tab U_d). These percentages are extrapolated forwards and backwards using linear regression, and international emission factors are derived from the USEEIO model data with EXIOBASE for 2017-2022, similarly extrapolated and adjusted as described above for the domestic data.

While the CBEI models started with the CEX, greater accuracy in calculating emissions can be achieved by using other household surveys for specific subcategories. The National Household Travel Survey (NHTS) can be used to model household vehicle miles traveled (VMT), and the Residential Energy Consumption Survey (RECS) can be used to model household energy usage. These are the most robust models that could be constructed using recent and relevant data, and in many cases are a very strong fit. For instance, at the state level, EcoDataLab's electricity and natural gas models have a goodness of fit R^2 value of about 0.87 and 0.72. This means they explain about 87% and 72% of the variation in household energy use, for their respective categories of energy. When compared with specific city and county-level data, these modeled results are typically within about 10% of the real-world data. This provides sufficient accuracy for historical back-casting and local tract-level estimates of variation.

In preparing consumption-based emissions inventories, CEX-based modeled estimates of expenditures on gasoline, electricity, natural gas, and other fuels are replaced with results from these other sub-models. With these models, direct and indirect (well-to-pump) emission factors are applied for both fossil fuels and electricity consumed directly by households.

This methodology combines local characteristics to inform regression modeling and scaling based on real-world national data to capture general trends. This allows for consistently tracking changes in the quantity of household consumption over time, and estimates the impact of consumption on emissions using best-available sources.

This consumption-based approach accounts for essentially all GHG emissions in the U.S. economy, allocated to households, government, and businesses. An earlier version of this methodology, reported in the Consumption-Based Greenhouse Gas Emissions Inventory of San Francisco from 1990 to 2015, found that the CBEI correlates very closely (within 10%) to the traditional inventory (see Figure 7 in the San Francisco CBEI report).

Limitations

Tracking changes and policy impacts: Unlike other CBEI approaches, the models described in this appendix allow for some ability to see the effect of policy and to track changes over time. The current approach offers this improved tracking by including more policy-relevant variables, including home size, household size, home ownership, education, income, population density, and vehicle ownership.

However, local changes in policy, behavior, infrastructure, and technology which might affect consumption or emissions in ways beyond the model variables are not included in the current approach. If a local policy changed consumption patterns or the carbon intensity of products or services consumed, we would not be able to monitor this with the current methodology. Additional data could supplement the approach in future studies.

Estimating errors: The current approach does not include an estimate of total error. Ideally, each estimate of consumption and emissions would include uncertainty bounds and analysis of error. Potential sources of error include reporting errors in household survey data, sampling error, model error, categorization error, and other errors typically associated with input-output models (in this case, the USEEIO). Presently, U.S. Census margins of error are propagated through the extrapolation and synthesis processes that generate the input variables to the household models, but the error is not further propagated through the household spending estimates or emission estimates. USEEIO emission factor error margins are not readily available.

Assumptions: Government and business emissions are scaled from statewide data based on local employment. QCEW data is only available at the county level. More granular estimates could be generated by using U.S. Census Longitudinal Employer-Household Dynamics (LEHD) data on Origin-Destination Employment Statistics (LODES), which includes employment numbers down to the block level. Emissions are allocated based on employment regardless of where the government or business spending may actually occur. This is due to the parallels with household emissions being allocated to home locations regardless of where the household spending may occur, and both the feasibility and availability of data and relevance for policy implications.

Lastly, the model assumes that price corresponds with “value added” economic activity. If households in an area purchase higher priced goods, then the methodology will linearly scale emissions up with prices. This scaling is appropriate if higher prices are the result of additional economic activity, such as importing products from abroad, but is problematic when prices are artificially raised, such as for branding purposes. Conversely, cheaper products will result in lower emissions in the model. Generally, it is assumed that price differences average out over thousands of households.